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Research Report

Engineering Science

NASA Grant NGR-52-029-004

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          Layer Wind Tunnel
          Faculty of Engineering Science
          University of Western Ontario

"Ground Wind Loads on Space Vehicles"

Progress Report 1 November 1966

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The new University of Western Ontario Boundary Layer Wind Tunnel was commissioned at the end of November 1965 and the research programme sponsored under this NASA grant to investigate the general problem of the ground wind loading of space vehicles was therefore one of the first tasks to which this new facility and its personnel were committed.

A large part of the intervening period has naturally been spent in evaluation of the wind tunnel characteristics. In this respect, it would appear that the intended performance of the tunnel has been realized and turbulent boundary layer thicknesses in excess of three feet are obtained with mean tunnel wind speeds up to approximately 50 ft./second. The boundary layer growth over a typical model surface is shown in Figure 1. The use of trips at the upstream entrance of the test section has been studied with a view of further increasing the thickness of the boundary layer without, however, introducing distortions to the turbulence structure generated by the shearing action at the ground surface. To this end, sets of low grids consisting of horizontal bars of graduated diameter and spacing have been made. Boundary layer thicknesses in excess of four feet have been obtained with the use of such grids.

In addition to the preliminary studies of the basic tunnel flow, progress has been made in the programme to study the interaction of the flow with dynamic models of space vehicle structures. An aeroelastic model of a Jupiter vehicle has been built and is presently under test in the wind tunnel. The model, installed in the wind tunnel, is shown in Fig. 2. The model was built to a linear scale of 1:30. It was constructed as a shell using balsa-wood diaphragm spacers and a skin thickness of approximately 1/16". The base of the model was mounted clear of the ground on a model of the launcher. A gimbal mounting is incorporated in the launcher to which the base of the model is attached. A rod attached to the model extends through the tunnel floor to a set of springs and a damping plate mounted between the pole pieces of an annular electromagnet. The springs provide rotational restraint to the gimbal and model and the damping unit can be adjusted by control of the current through the electromagnet. The spring restrained gimbal mount together with the flexibility of the model itself give rise to a fundamental vibration mode comparable with that of the full scale Jupiter as measured by NASA Langley. The velocity scaling employed in the testing is 1 ft./sec. on model equivalent to 3 mph full scale.

The primary purpose of these tests at present hand is to produce results which can be compared with full scale tests being conducted by NASA Langley on a full scale Jupiter vehicle located at Wallops Island. In the wind tunnel tests the response of the model

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Jupiter is being studied employing two different boundary layer flows corresponding to full scale roughness lengths of approximately 0.4 and 10 inches and values of critical damping ratios in the range .005 to .05. Tests will also be carried out in which vertical trips are placed on the model in order to induce an earlier formation of the turbulent boundary layer on the model. This is a conventional procedure in static tests for simulating behaviour representative of higher Reynolds Numbers.

A representative set of results for one of the above parameters with a smooth model surface is given in Fig. 3. The parameters of the test are noted on the diagram. Mean velocities at the top of the model, designated $\bar{V}_1$, are used in Fig. 3. Mean and RMS deflections at the top of the model are normalized by H, the maximum height above the launcher (H full scale = 57.46'). The mean velocity and turbulence intensity profiles are given in Fig. 4.
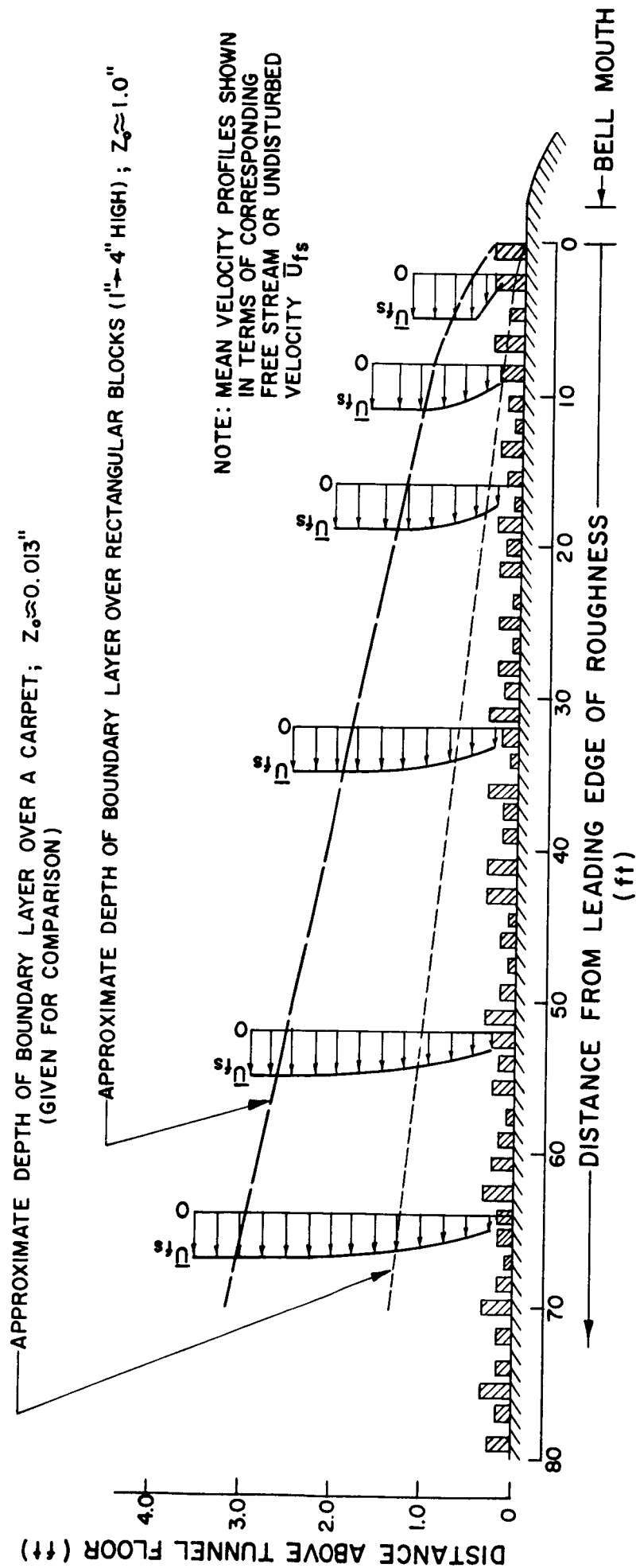
In addition to the above tests, a number of tests have been carried out on the aeroelastic behaviour of simple prisms of square and rectangular cross section, pivoted at the base on gimbals as with the Jupiter model. These have been tested under various flow conditions. The general characteristics of the response are indicated in Fig. 5, which compares the response of a prism in uniform and turbulent flow. This diagram shows that the presence of turbulence has a modifying influence on the lateral vortex shedding excitation and introduces drag excitation not usually present in uniform flow.

The development of a linearlized hot wire system has been completed. With this equipment the turbulence properties of the boundary layer flow, which will be essential for the proper comparison of the behaviour of the wind tunnel Jupiter model with the Wallops Island full scale prototype, will be studied upon acquisition of suitable statistical analysis equipment. For this purpose an order has been placed for a Technical Measurement Corporation correlation computer and probability analyzer and punched card output unit. The total cost of this equipment is being paid for on an approximately 50-50 basis from NASA grant support and other sources of funds available to the wind tunnel.

During the year, the grantee made two visits to Langley Research Center; on the first occasion to attend the conference on Ground Wind Loads on Launch Vehicles at which he presented two papers published in the proceedings. The purpose of the second visit was to discuss with Messrs. G. Rainey and W. Reed of the Aeroelasticity division, the problems relating to the full scale Jupiter programme and its scope and other salient matters.

1 November 1966

University of Western Ontario

NOTE: MEAN VELOCITY PROFILES SHOWN IN TERMS OF CORRESPONDING FREE STREAM OR UNDISTURBED VELOCITY $\bar{U}_{fs}$

APPROXIMATE DEPTH OF BOUNDARY LAYER OVER A CARPET; $Z_0 \approx 0.013''$ (GIVEN FOR COMPARISON)

APPROXIMATE DEPTH OF BOUNDARY LAYER OVER RECTANGULAR BLOCKS ($1'' \rightarrow 4''$ HIGH); $Z_0 \approx 1.0''$

DISTANCE ABOVE TUNNEL FLOOR (ft)

DISTANCE FROM LEADING EDGE OF ROUGHNESS (ft)

BELL MOUTH

DEVELOPMENT OF BOUNDARY LAYER
OVER TYPICAL TUNNEL SURFACES

FIGURE 1

1:30 SCALE AEROELASTIC MODEL OF
VEHICLE IN WIND TUNNEL
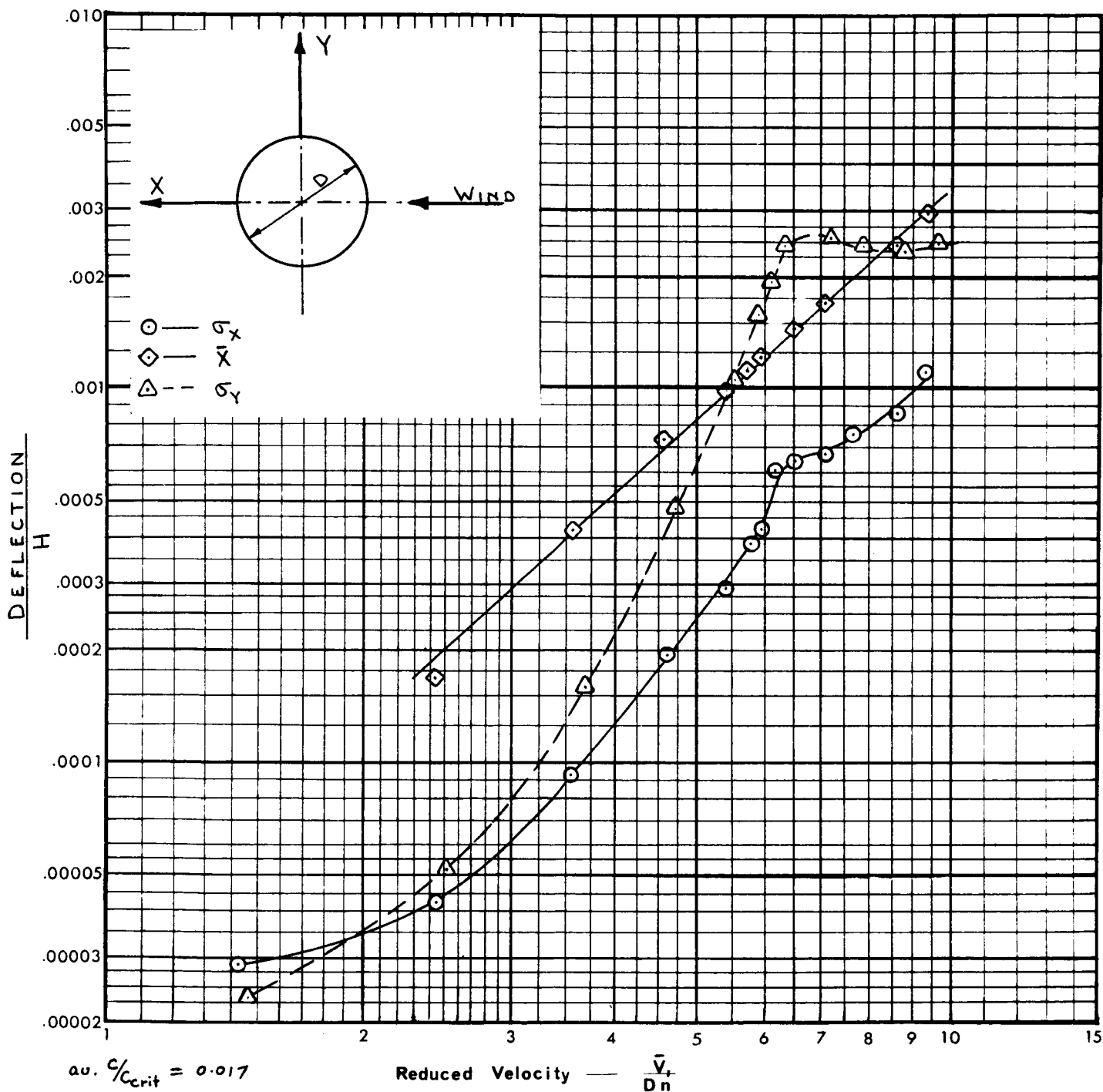
FIG. 2

University of Western Ontario Boundary Layer Wind Tunnel Laboratory
London   Canada

Test: 1:30 AEROELASTIC   Date: Nov. 3/66
JUPITER MODEL IN MODERATELY ROUGH FLOW $\left(Z_{o_{full scale}} \approx 10''\right)$
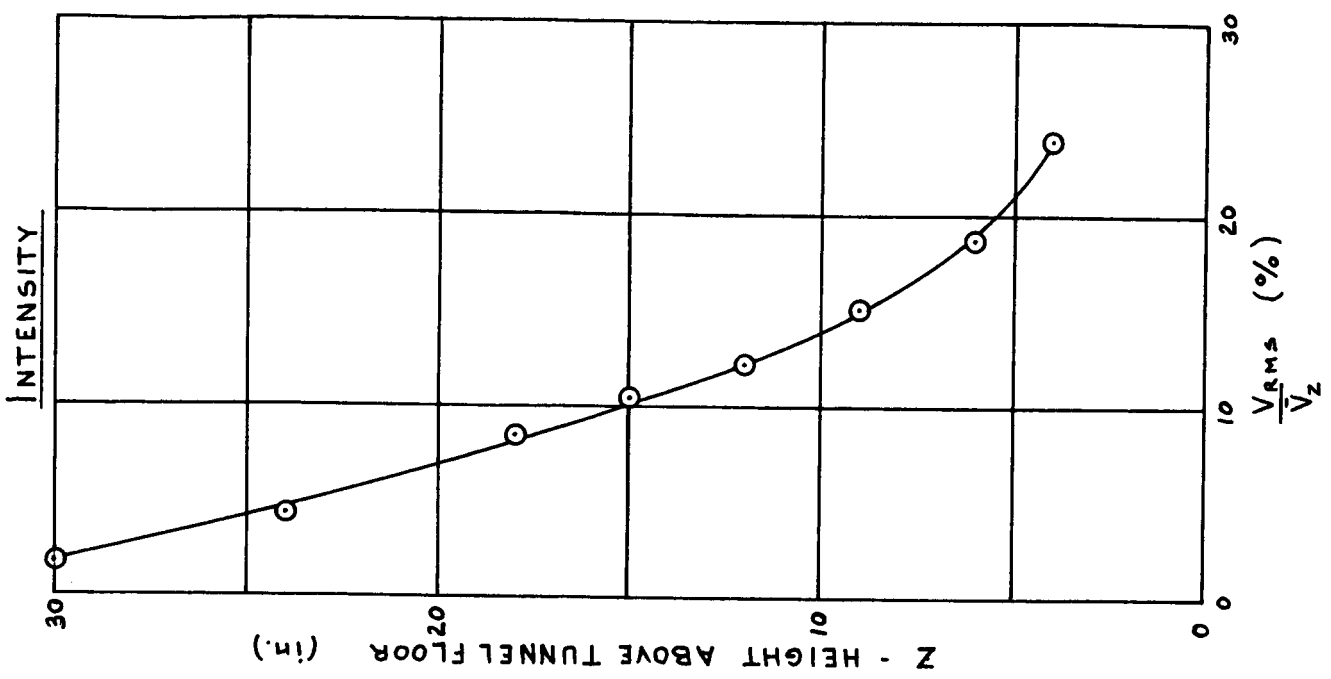MODEL SURFACE - SMOOTH

av. $C/C_{crit} = 0.017$ Reduced Velocity — $\dfrac{\bar{V}}{Dn}$
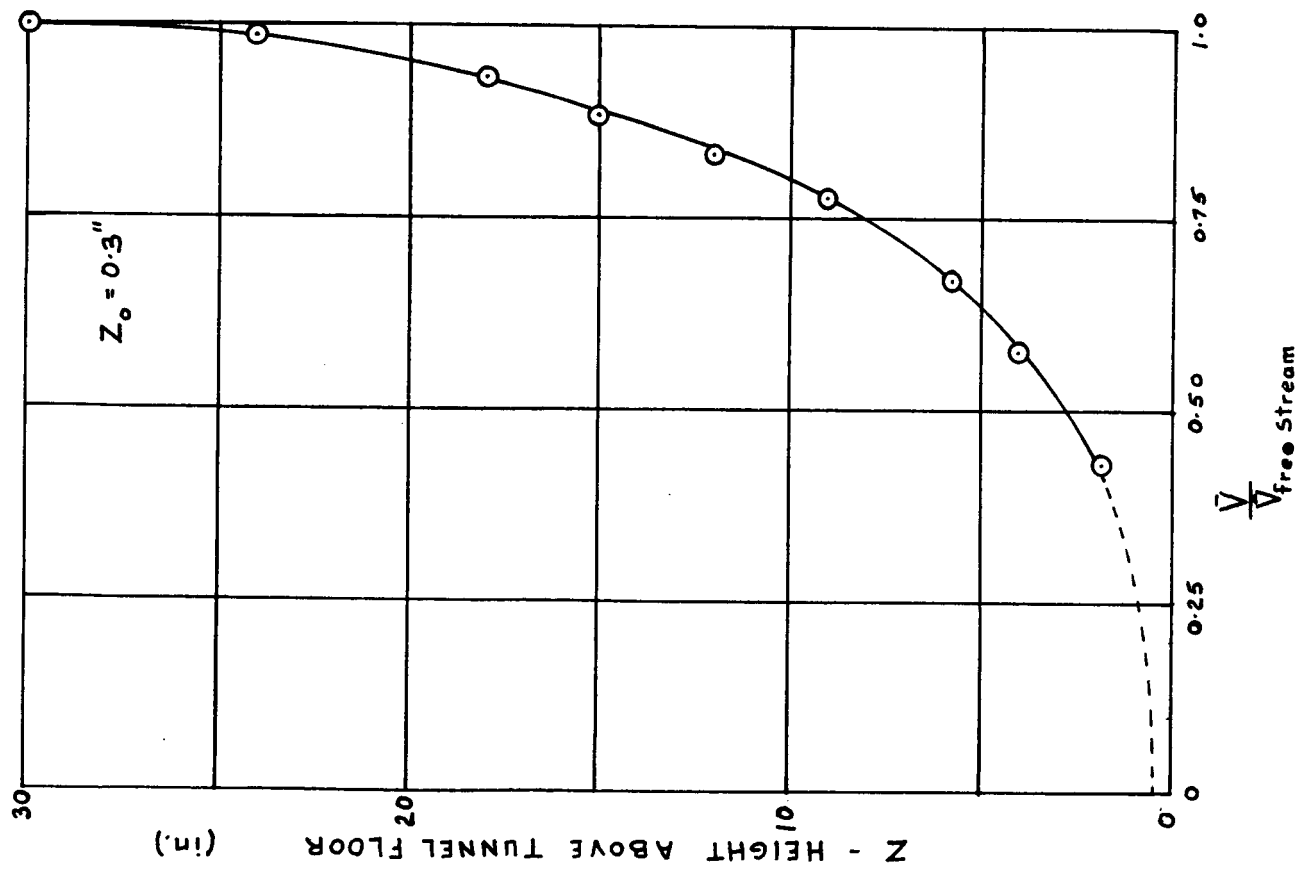
$n_x = 15.2$ c.p.s.

$n_y = 14.9$ c.p.s.

RESPONSE OF AEROELASTIC JUPITER
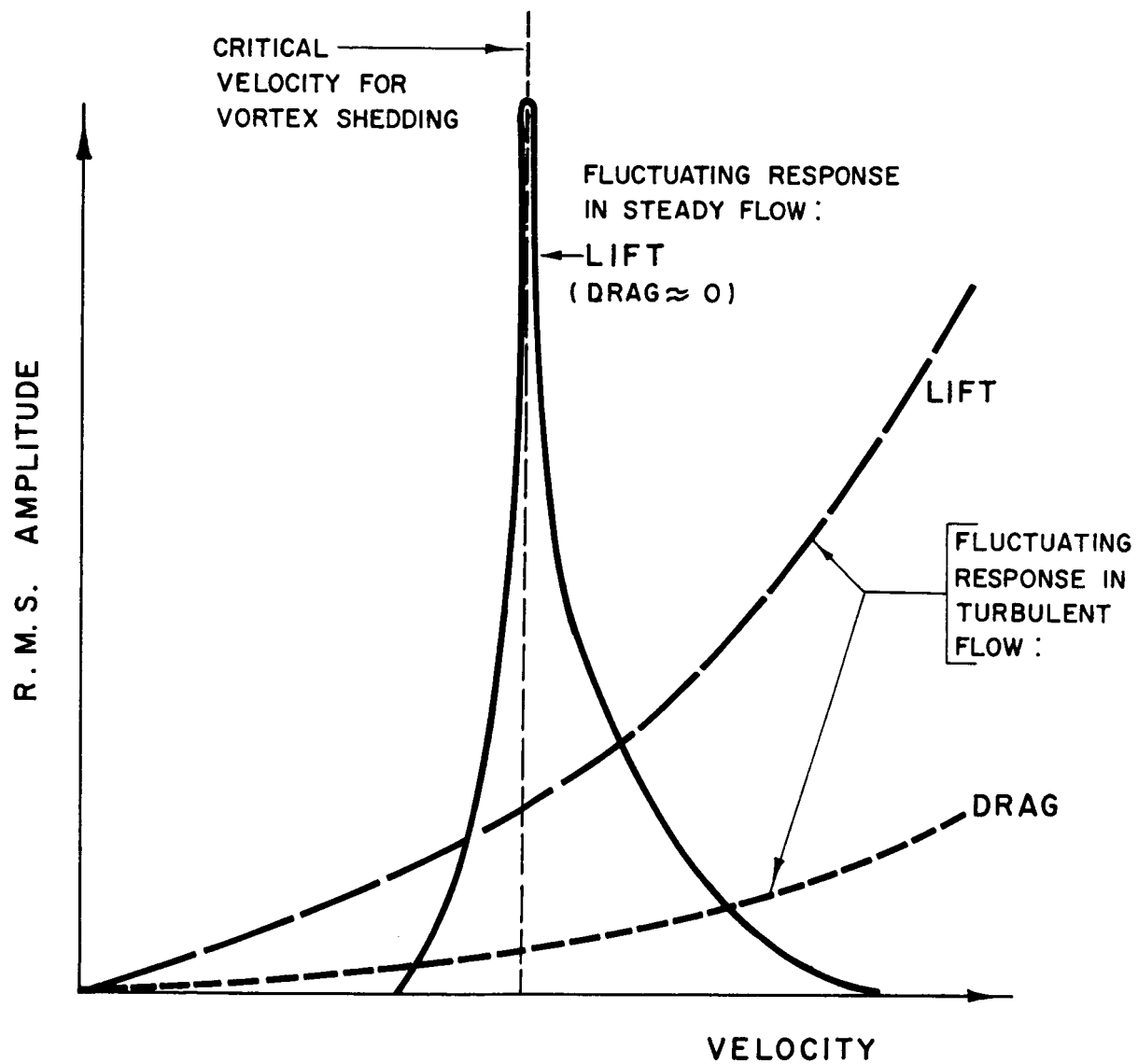# MODEL IN TURBULENT BOUNDARY LAYER   FIG. 3

PROFILE OF LONGITUDINAL TURBULENCE INTENSITY

MEAN VELOCITY PROFILE

FLOW CHARACTERISTICS

FIG 4

COMPARISON OF CHARACTERISTIC RESPONSES OF BLUFF BODY TO SMOOTH AND TURBULENT FLOW

FIG. 5